NORTHEASTERN FOREST EXPERIMENT STATION

Semiannaul Report
Watershed Management Research

October 1, 1967 - March 31, 1968

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NORTHEASTERN FOREST EXPERIMENT STATION

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PROJECT 1601 - WATER YIELD IMPROVEMENT

Transpiration Reduction on a Clearcut Watershed

Substantial increases in water yield have continued through two summer seasons in our clearcut watershed because of reduced transpiration. For the major part of the growing season, June-September, first- and second-year increases in streamflow were 12.2 and 9.0 area inches, respectively (Table 1). Although precipitation during the 1967 season was 2 area inches less than in 1966, streamflow augmentation was only 3 area inches less for a comparable period. Gradual reductions in streamflow from clearcut watersheds are common after the initial first season increases. In spite of this, we suspect at least part of 1 inch of the streamflow decline (we assume that 2 inches less precipitation accounted for the remaining difference) may have been caused by transpiration from sprouting stumps not killed by the herbicide bromacil applied the previous growing season. If the transpiring sprouts did account for the 1-inch difference, this suggests that when evaporation losses are replenished and soil water depletion comes to equilibrium, any excess water (precipitation) beyond these needs contributes to streamflow. If next summer's rainfall is below normal, we may be able to determine if this notion is correct and obtain an approximation of the soil water equilibrium requirement. Completion of an application of 2,4,5-T to individual stump sprouts at the end of last summer hopefully will reduce transpiration losses next summer.

Table 1.--Growing Season Precipitation and Streamflow for a Clearcut Watershed

	Precipitation (area inches)			Streamflow (area inches)					
				1966			1967		
	11-Year Avg.	1966	1967	Treated 1/	Untreated 2/	Diff.	Treated 1/	Untreated 2/	Diff.
June	3.5	4.2	3.2	3.3	1.4	1.9	2.0	.8	1.2
July	4.2	3.9	4.4	3.1	.2	2.9	2.7	.4	2.3
Aug	4.0	7.7	5.4	5.8	1.2	4.6	3.6	.6	3.0
Sept	3.8	4.6	5.3	3.8	1.0	2.8	3.9	1.4	2.5
	15.5	20.4	18.3	16.0	3.8	12.2	12.2	3.2	9.0

1/ Actual streamflow from clearcut watershed.

2/ Streamflow prediction in an uncut condition based on equation developed in relation to adjacent check watershed.

Water Quality Studies

Aside from our keen interest in water yields arising from the clearcutting experiment, our excitement is growing in the realm of water quality. In cooperation with Dartmouth College and Yale University, perhaps unparalleled studies of both water quantity and quality are underway. Several recent publications (see Publications List) describe the input and output flows of chemical nutrients on several gaged watersheds at Hubbard Brook. Perhaps the most dramatic results to date indicate as much as 50 times the normal concentration of nitrate nitrogen appeared in streamflow from the clearcut watershed. Also, concentrations of dissolved calcium, magnesium, sodium, and potassium increased from 3 to 20 times greater than in streamflow from undisturbed adjacent watersheds (Bormann et al. 1967).

Potential Evapotranspiration -- Definitions

Two definitions of potential evapotranspiration (PE) are in common use, but are often not clearly distinguished. The original definition, formulated by Penman and Thornthwaite, is -- that evapotranspiration which would occur from a short, complete, green, growing plant cover of unlimited extent, never short of water. The PE concept is now often applied to any given surface, bare soil, row crop, forest, open water, etc., and is then defined as -- that evapotranspiration which would occur from any given site if water supply were never limited. We have begun calling the former definition "restricted PE" and the latter "general PE."

General PE is controlled by atmospheric factors: radiant energy, air temperature, air humidity, wind; and by surface factors: albedo, canopy roughness, and stomatal resistance. The restricted definition essentially standardizes the surface factors and fixes them, so restricted PE is governed only by the atmospheric factors. PE calculations by the Penman method for instance thus give restricted PE, which cannot be considered to be equal to the general PE for a forest.

Since all values of PE for forests are only estimates of the desired general PE, and since the various methods of estimating PE give different values, none of which may be the correct one, it is always necessary to specify the calculation method used when PE values are given.

A station paper elaborating on these concepts is being written.

Winter Hardwood Albedo

We are beginning a study of solar radiation relations in hardwood stands in winter. Knowledge of the relative amounts of canopy absorption and snow absorption as a function of sun position, slope, aspect, and stand characteristics is required for studying the energy balance of snowmelt in hardwoods. Initial results indicate that the canopy may absorb two to five times as much radiation as the underlying snow, yielding a canopy albedo of about 0.2. Radiation absorbed by the canopy is converted to longwave radiation and sensible heat, both of which can be transmitted to the snow

surface. When radiation melt predominates, melt may therefore be more rapid under hardwoods than the open, if there is little or no slash above the snow surface.

In the two springs since clearcutting of the south-facing Hubbard Brook watershed 2, snowmelt has been advanced about 3 to 6 days over the adjacent hardwood areas. But the relatively heavy slash has settled now and this winter (1968), for the first time, snow completely covers the slash. We are predicting that, at least early in the melt season, the hardwood areas will melt more rapidly than the clearcut. We shall see.

In conjunction with this study we have developed a theoretical model for light transmission through a leafless hardwood canopy. We would like to know if any data are available that could be used to test this theory. Information on light transmission for different dates and times, basal area, height, mean diameter, slope, and aspect are required.

Weir-Flume Discharge Comparisons

Two Hubbard Brook watersheds are gaged with San Dimas flumes in tandem with 1-foot-deep, 90° V-notch weirs. A by-product of this arrangement is the opportunity to check the flume rating curves at low stages using weir discharge values.

For watershed 5, which has a 3-ft.-wide flume, we checked 77 instantaneous points falling between flume stages of .10 and .22 ft. Values from the rating curve (developed at San Dimas Experimental Forest) compared favorably with weir discharge. Averages of the 77 points were 1.61 c.f.s. for the weir and 1.62 c.f.s. for the flume. When plotted against a 1:1 ratio line, the points showed very little scatter and were about equally distributed above and below the line, indicating the rating curve is suitable at low stages.

Watershed 6 has a 2-ft.-wide flume; the rating curve in use was taken from unpublished work by Burmel in 1947. Averages of 117 points occurring between flume stages of .10 and .30 feet were 1.52 c.f.s. for the weir and 1.40 c.f.s. for the flume. More important is the plotting of the points against a 1:1 line, which showed the flume discharge to be consistently lower over the entire range of stage. Thus a change in the rating curve for the 2-ft. flume may be necessary.

The stages checked above account for only a small portion of the measurement range of the several-feet-deep flumes. Rating checks for higher stages will have to employ another method.

-- R. S. Pierce
C. A. Federer
J. W. Hornbeck

More Runoff than Rainfall

Watershed 8 is the most efficient watershed on the Fernow. For a nine year period, dormant season streamflow has averaged 109 percent of precipitation. Study of stream-discharge measurement and weir rating did not explain this anomaly. A resurvey of the watershed boundary also failed to explain the excessively high yield. Watershed 8, approximately 47 acres in size, is located on an old farm abandoned about 1940. The weir was built in 1956 and records were started November 1, 1957 to evaluate the effects of afforestation on streamflow. The following investigation was initiated to explore the possibility that precipitation estimates might be too low.

Wind could have a greater effect on precipitation estimates in Watershed 8 than on the more densely forested Fernow watersheds. The last vegetation survey in 1958 indicated that 29 percent of the area was forested and although the forested acreage has increased since that time, the trees are small and stocking is light over much of the watershed. The topography is fairly steep with slopes extending up to 50 percent.

Four standard gages, one shielded gage, and one recording gage sample precipitation on Watershed 8. A standard gage was tilted normal to the slope adjacent to each of the vertical standard gages. The precipitation gages are located on slopes varying from 25 to 50 percent. The precipitation caught in the tilted gage was divided by the cosine of the slope angle to correct the catch to that for a horizontal surface.

Twenty-seven one gallon cans were placed in openings scattered throughout Watershed 8. Precipitation was measured in these cans at the same time it was measured in the tilted and standard gages. An isohyetal map (Figure 1) was constructed based on precipitation catch in the gallon cans and the 4 standard gages. Average precipitation was computed from the isohyetal map. Precipitation estimates by each sampling method are summarized in Table 1.

Figure 1.--ISOHYETAL MAP FOR WATERSHED NO. 8 (47.07 acres)

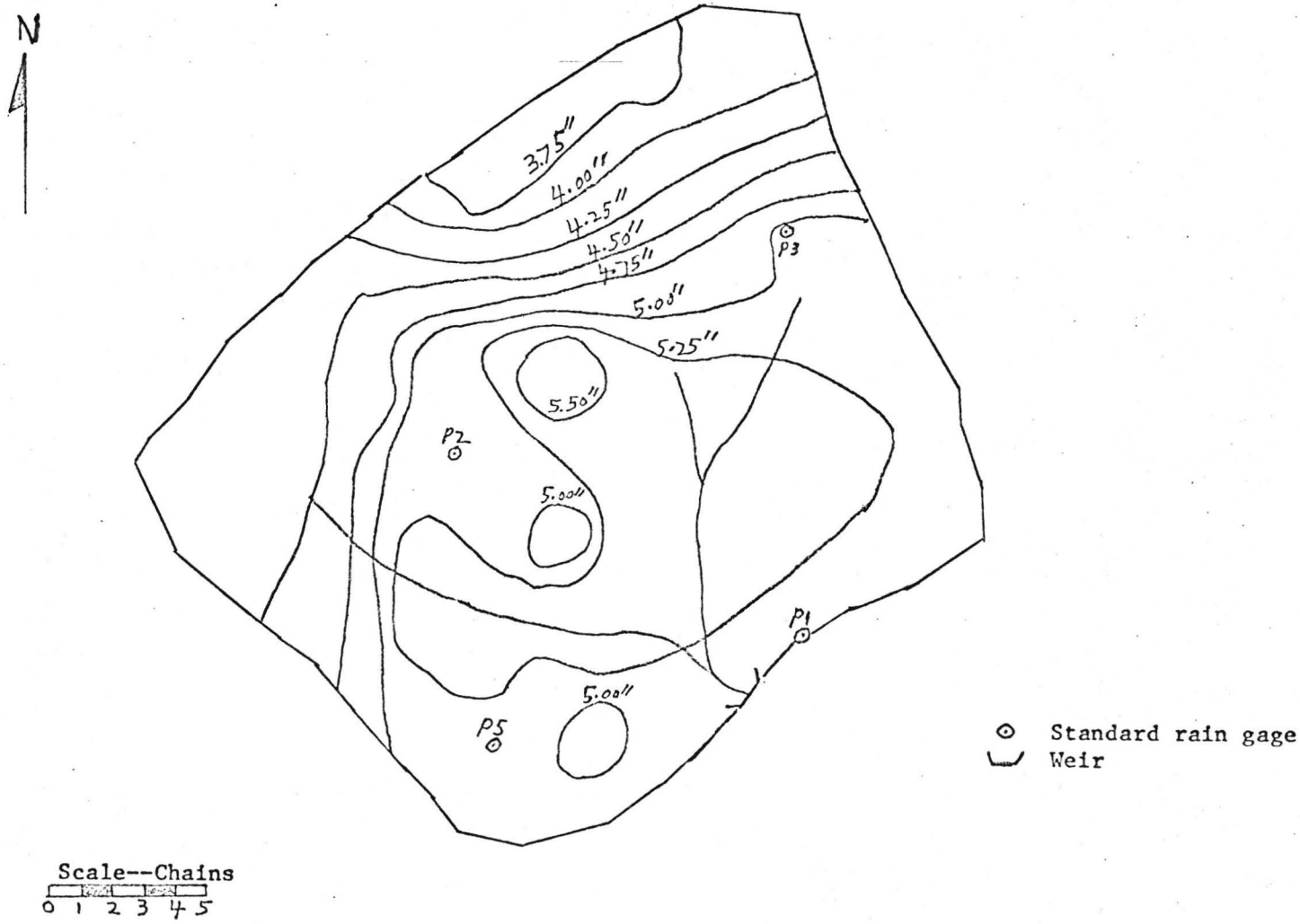


Figure 1.--ISOHYETAL MAP FOR WATERSHED NO. 8 (47.07 acres)

Table 1.--Comparison of several methods for estimating precipitation on Watershed 8

Period	Tilted Gages	Std. Gages	Gal. Cans	Isohyetal Method	Shielded Gage
	Inches				
11/30/67-12/3/67	2.18±.084[1/]	2.17±.084	2.15±.486	_____	2.29[2/]
12/10/67-12/12/67	1.46±.050	1.43±.134	1.35±.396	_____	1.52
12/12/67-12/20/67	.22±.020	.22±.028	.19±.076	_____	.23
12/20/67-12/27/67	1.28±.078	1.31±.141	1.26±.276	_____	1.41
Total inches recorded	5.14±.122	5.13±.198	4.95±1.108	4.93	5.45

1/ Standard deviations based on 95 percent confidence interval.

2/ Based on one gage.

About 10 percent of the average annual precipitation fell during the study period. The tilted gages did not appreciably affect the precipitation catch. At each location the tilted gages appeared to be tilted away from the prevailing wind. Snow deposited on the back of trees and the tilted gage at P-5 indicated that one storm came from the southwest. The inclination of precipitation from the vertical was influenced more by the prevailing wind than by topography in Watershed 8. Tilting gages normal to the slope can be expected to have little effect on gage catch.

The shielded gage indicated a catch 6.2 percent greater than the average catch of all the standard gages. When catch for the shielded gage (P1A) was compared with catch for the adjacent standard gage (P1) for a two year period, the difference was about +3.5 percent. Because of the large areal variation in precipitation, careful placement of gages becomes more important than shielding them.

Catch in the gallon cans (Table 1) spread from 3.66 to 5.51 inches, decreasing with increasing elevation on the southern exposure of Watershed 8. This relationship was not apparent on the northern exposure, probably due to variation in local winds. This influence of topography on precipitation accounts for the large standard deviations. Stratifying by using the 12 cans located between the 5.00- and 5.25-inch isohyetal lines, where all the standard gages are located, gave a mean of 5.20±.242. This catch compares well with standard gage catch and strengthens confidence that decreased catch at higher elevation does not reflect some inadequacy of the cans.

The isohyetal map shows the actual precipitation distribution in Watershed 8. The average weighted precipitation for Watershed 8 was computed by planimetering the area between each isohyetal line and multiplying this figure by the average gage catch for each area. The isohyetal map indicates that standard gages are all placed in areas of highest rainfall.

The evidence obtained suggests that ground water holds the answer to our rainfall-runoff anomaly. This possibility will be explored in the future.

---James N. Kochenderfer

Subsurface Flow on Plots of Sandstone and Limestone Soil

We are in the final stages of installing our first subsurface flow plot. A 50-foot wide collection system has been installed perpendicular to, and at the base of, a 175 foot slope. A 0.8-foot head HS flume with an FW-1 recorder measure flow from the plot. The collection system was completed last November; since then outflow has been almost continuous. On occasion, flow has exceeded 400 gallons per hour.

Thanks to Austin Helmers of the Institute of Northern Forestry, we have 3 recording piezometer systems to use on our plot. Two have been installed on the plot while the third has been located on the same contour as the collection trench but some 40 feet off the plot. They appear to be quite sensitive to changes in the depth of saturated soil due to snowmelt and heavy rainfall and we are presently using them to estimate the hydraulic conductivity in the saturated layer. The piezometer traces indicate a continuous rise and fall of the water table just behind the collection trench. We expect this may be due to minor fluctuations in barometric pressure and are investigating it at present.

Current plans call for the installation of a second subsurface flow plot approximately the same size as the first. The major difference will be soil type. The first plot is located on a Calvin loam soil while the second will be on a heavy Belmont silt loam, a limestone soil. Most of the hydrological work here at Parsons has avoided the limestone areas like the green plague. This thinking has been more than justified, but we feel that perhaps it is time to expand some of our research to include these areas. So many problems arise with watershed selection and calibration that we consider it impractical to select an entire limestone watershed as part of our program. Instead, we hope to learn more about subsurface flow on limestone soils with the plot approach.

Except for lateral trenching to be done this summer, the first plot is nearly complete and we hope to have the second one operational in a month or so. Now all we need is a normal amount of rain.

---Charles A. Troendle

Results and Plans for Half-cut Watersheds

November 1, 1967 marked the end of three full years since clearcutting halves of Watersheds 6 and 7. The lower half of 6 and the upper half of 7 were maintained vegetation-free by spraying with 2,4-D and 2,4,5-T during those years. Annual increases in streamflow are tabulated below, all significant at the 0.05 level. Flow-duration curves establish that

Water Year	Watershed 6	Watershed 7
1965	4.14"	5.64"
1966	7.88"	7.10"
1967	5.21"	9.50"

most of these increases came during periods of low flow, usually in late summer and early fall. Changes in the frequency of individual flow events were significant at the 0.05 level for most of the flow classes below one csm but flow frequencies above one csm never increased significantly.

Now these watersheds are entering a second phase of treatment. The formerly uncut halves have been logged and pulp cutters are removing everything saleable that remains. The Fernow logging crew will cut all standing stems by May 1, after which these watersheds will remain vegetation free for at least 2 years. The 1967 streamflow increase from Watershed 7 reflects this new phase of treatment. Here, cutting during the 1967 growing season caused the disproportionate increase of 9.50 inches, some of which originated on the freshly cut lower half of the watershed.

The problem of maintaining 120 acres vegetation-free has given us some anxious moments. First, we could not buy 2,4,5-T. Hopefully, this problem was solved by a mixture of 2,3,6-TBA, 2,4-DP, and 2,4-D proclaimed by the manufacturer to be one of the best formulations yet devised for hardwood control. A labor problem was less easily solved. During the past 3 years, much of our aide time was spent on vegetation control on clearcut half-watershed. Now, with two full watersheds clearcut, use of aides alone for this work is out of the question. Employment ceilings and the probability of appropriations cuts eliminated conventional hiring, Nevertheless, we may have found a solution. The work study program for college students (Economic Opportunity Act

of 1964, P. L. 88-452) can provide us with five or six summer students from a local college who are not counted as federal employees. Since we pay only 20 percent of their salaries, their cost is within our means. Although these students are not yet toiling on our watersheds, we pass this information along to those faced with similar problems.

---James H. Patric

PROJECT 1603 - FOREST HYDROLOGY AND URBAN FOREST ENVIRONMENT

Short on travel money, Project people spent the past six months close to their desks, enjoying that unaccustomed luxury of doing solely what they would--research.

Municipal Watersheds

To determine the extent and current management practices of forested municipal watersheds in the Northeast we are utilizing a questionnaire, the mailing of which is currently underway. State agencies, forest survey divisions, National Forests, and personal contacts have been queried to determine the location and ownership of such watersheds. Initial mailing will approach 1000 questionnaires. A copy of the questionnaire along with the cover letter explaining its use is enclosed in this report.

---E. S. Corbett

In those odd moments when not involved with Division administrative tasks, Reinhart is trying to finish up the study on dependable Yield of a Municipal Watershed (Princeton, W. Va.). Several different estimates of yield have been made based on a variety of data; the job now is to write these up and apply judgement in order to determine the best estimate or a weighted average that will be of practical use.

---K. G. Reinhart

Regional Studies

Howard Lull spent the greater part of the period looking for trends in streamflow records of 23 Eastern watersheds. Watersheds range in area from 18 to 487 square miles; records (the longest we could find) range from 25 to 62 years. Trends have been identified principally from mass curves of measured annual runoff versus predicted (from Pete Black's computer program for Thornthwaite's water balance) and from plottings of measured minus predicted annual runoff. Definite long-term trends are evident in records of 13 watersheds. Urbanization seems to be a causative factor in at least two cases; in others the trends appear related to long-term changes in proportion of the watershed in farmland (or, if you will, in forest). In still others, the trends pursue a course contrary to selected dogma. Professor-cooperator Art Eschner (Syracuse) mans the computer on this study and provides sage counsel.

---H. W. Lull

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET — UPPER DARBY, PA. 19082

IN REPLY REFER TO:

4300

Will you help us in preparing a directory of municipal watersheds and watershed managers? The Northeastern Forest Experiment Station is currently preparing such a directory for an area encompassing New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Ohio, and Kentucky. We define a municipal watershed as one in which the primary function is to provide domestic water supplies, whether in private or public ownership. Lands surrounding reservoirs are included in this definition. A municipal watershed manager, therefore, is an individual whose primary responsibility is the care and management of such a watershed.

The directory, when compiled, will serve to identify watershed managers on a regional basis and improve opportunities to exchange information on problems of mutual interest. And it will give us contacts with people who are managing watersheds and enable us to consider their problems in developing our research programs. The directory also will result in an up-to-date estimate of the extent and importance of publicly and privately owned municipal watersheds in the Northeast.

Please fill out the enclosed questionnaire and return it in the self-addressed envelope. No postage is needed. If the answers to any of the questions are not readily obtainable or are only approximations, please state so on the questionnaire. Use the back side of the questionnaire for explanations, extensions of answers, or any other points you may wish to make. Additional copies of the questionnaire are available if you need them. Information supplied for questions 10 through 16 will be kept confidential, and will not be identified in any published material without your prior approval.

Check item 20 of the questionnaire if you would like a copy of the directory after publication. Thank you for your cooperation.

Sincerely yours,

Edward S. Corbett
Hydrologist, Municipal
Watershed Research

Enclosure

Budget Bureau No. 40-S67132

Approval Expires December 1968

QUESTIONNAIRE FOR COMPILING A DIRECTORY OF MUNICIPAL WATERSHEDS AND WATERSHED MANAGERS

1. Name _____

2. Business Address _____

_____

_____

3. Are you the manager of a municipal watershed? (Check)

Yes ☐ No ☐

If no, complete items 18 - 20 and return the questionnaire.
If yes, complete items 4 - 20 and return the questionnaire.

4. What is your administrative title? _____

5. What municipality (ies) do you serve? _____

_____

6. Indicate whether the watershed land you manage is: (Check)

Owned by a municipality. . . . . ☐
Owned by a private company . . . . . ☐
Administered by a state government agency. . . ☐
Administered by a federal government agency. . ☐

7. What is the size of the watershed which you manage?

Land area. . . . . _____acres.
Inundated area (reservoirs, lakes, etc.) _____acres.
Percent of land area forested. . . . . _____

8. If the size of the total drainage area contributing to your water supply is different from the combined acreage shown above, what is the total drainage area? . . _____acres.

Percent of total drainage area forested . . _____

9. Location of watershed:

Counties _____

Nearest Post Office _____

10. Is watershed land taxed by the counties in which it is located? (Check) Yes ☐ No ☐

If yes, what is the amount per acre per year? $_____

11. Is timber harvesting allowed on the watershed? (Check)

Yes ☐ No ☐

If yes, check the purposes and specify the average annual volume or area affected:

A. Sawtimber production . . . ☐ _____ board feet.

B. Pulpwood production. . . . ☐ _____ cords.

Indicate whether this timber is harvested primarily for:

Water-yield improvement. . . . . ☐

Timber products for municipal use. . . . . ☐

Municipal income . . . . . ☐

Fire protection (fire breaks, access roads, etc.). . ☐

C. Timber stand improvements:

Thinning . . . . . ☐ _____ acres per year.

Pruning. . . . . ☐ _____ acres per year.

D. Salvage or sanitation:

Removal of diseased and insect-infested trees only . . ☐ _____ board feet.

E. Other (specify) _____

_____

_____

_____

12. Are herbicides used in the management of the watershed?
(Check) Yes ☐ No ☐

If yes, what types are used? (Specify)

_____

_____

13. Are the following data collected on the watershed? (Check)

Precipitation ☐ Streamflow ☐ Temperature ☐
Humidity ☐ Evaporation ☐

14. Indicate the types of recreation allowed on the watershed:
(Check)

Swimming	☐	Ice skating	☐
Boating	☐	Hunting	☐
Fishing	☐	Hiking	☐
Picnicking	☐	Camping	☐
Skiing	☐	Horseback riding	☐
		None	☐

Other (specify) _____

_____

_____

_____

_____

_____

_____

_____

15. Indicate the main problems in managing your watershed. Check the box that most accurately reflects the degree of each problem.

	Very serious	Serious	Not serious
Water yield improvement	☐	☐	☐
Water quality control	☐	☐	☐
Timber management	☐	☐	☐
Marketing forest products	☐	☐	☐
Recreation pressures	☐	☐	☐
Others (specify)			
_____	☐	☐	☐
_____	☐	☐	☐
_____	☐	☐	☐
_____	☐	☐	☐

If no problems, check here. None ☐

16. If you indicated water quality control as a problem area, what are the sources of contamination? (Check)

Contamination from industrial sources (factories, etc.) ☐

Contamination from domestic sources (subdivisions, waste treatment plants, etc.) ☐

Contamination from recreational sources (garbage, waste effluent, etc.) ☐

Contamination from logging on the watershed ☐

Other (specify) _____

_____

_____

17. Which publications do you think would serve as the best media for municipal watershed management research results and discussions? (Check)

Journal American Water Works Association	☐	Journal of Forestry	☐
Journal Soil and Water Conservation	☐	Journal New England Water Works Association	☐
U.S. Forest Service Research Papers	☐	Water and Wastes Engineering	☐

Other (specify) _____

_____

_____

18. Please list the names and addresses of other municipal watershed managers whom you know in the northeastern area (New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Ohio, Kentucky).

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

19. If you wish to be placed on the mailings lists to receive any of the following publications free of charge, please indicate. (Check)

1. Quarterly list of U.S. Forest Service Watershed Research Publications. ☐

2. Northeastern Forest Experiment Station Research Publications. ☐

3. Lull, H. W. 1966. An annotated bibliography of watershed management research by the Northeastern Forest Experiment Station, 1931-65. U. S. Forest Service Research Paper NE-48, 37 pp. ☐

4. Lull, H. W., and K. G. Reinhart. 1967. Increasing water yield in the Northeast by management of forested watersheds. U.S. Forest Service Research Paper NE-66, 45 pp. ☐

20. Would you like to receive a copy of the directory upon its completion? (Check) ☐

PROJECT 1604 - STREAM REGIMEN AND WATER YIELDS

The Cooperative Watershed Project has been active in the banquet circuit during the past six months. This project has been responsible for some seven oral presentations during the period. Such activities are hard on the waistline and current research activities.

Solar Radiation Relationships

The investigations of albedo above conifers canopies previously reported upon by this project have been extended to include northern hardwoods. A tramway 100 feet long and 65 feet high, 10 feet above the general plain of the canopy, has been constructed and data collection is underway.

Solar radiation and albedo values from a clear day in May are presented in Figure 1. The diurnal pattern of albedo exhibited here is of the same magnitude as that noted in the Red Pine albedo investigation. Tree leaves at this measurement period were approximately half size.

Snow Interception

The continuing investigation of the disposition of intercepted snow has produced more interesting information this quarter.

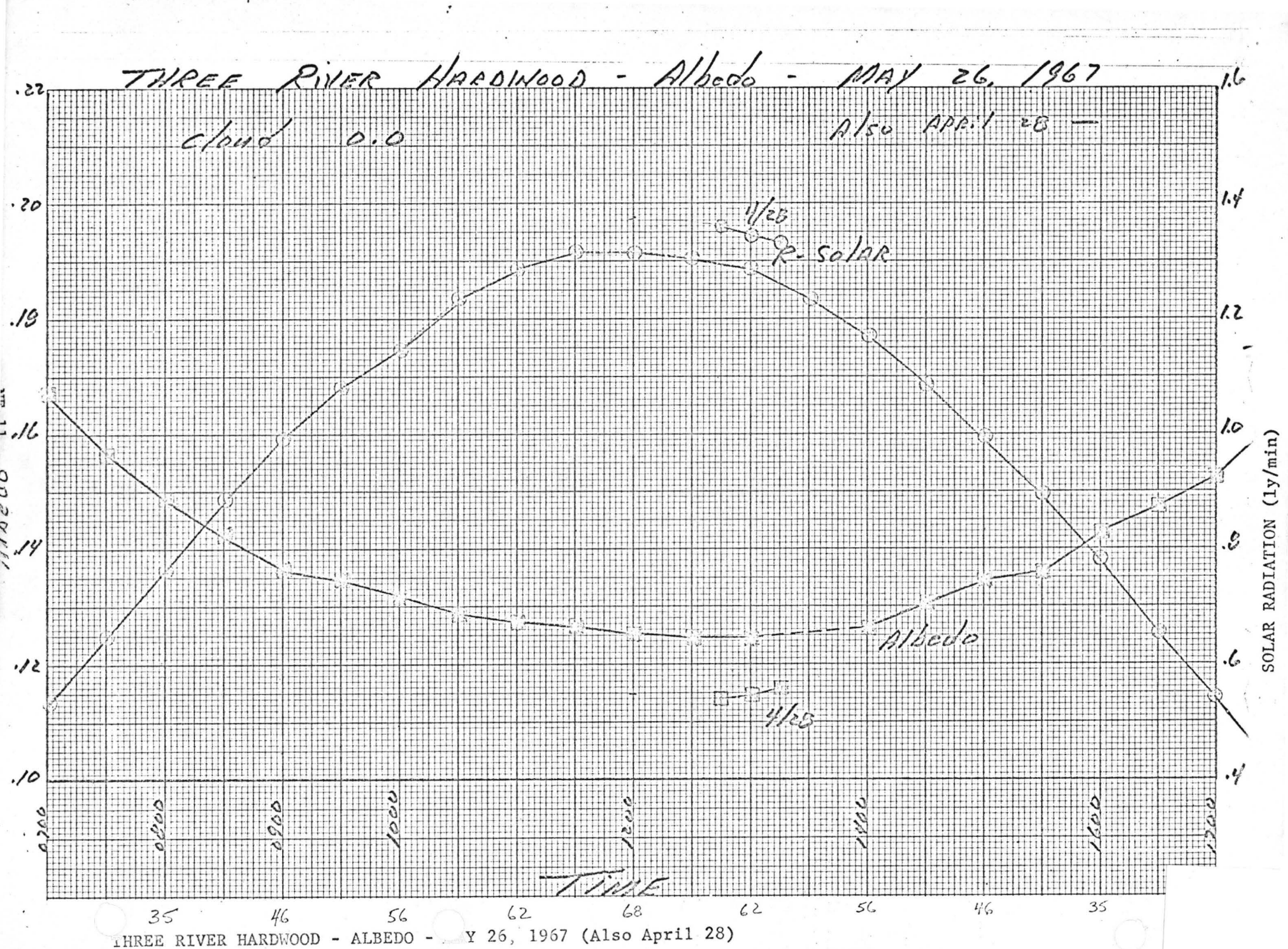
As previously reported, three small conifer trees, 5 to 6 feet high and mounted on platform scales, are being monitored for weight changes during and following periods of snowfall. Incident solar radiation is measured above the trees and net radiation, air temperature and relative humidity are measured within and above the sample trees.

Information from a storm of 2.9 inches depth which occurred on the night of February 1 - 2 is presented in the following graph, Fig. 2.

Solar radiation when it is available at relatively high intensity, is effective in causing evaporation. When it is not, evaporation may be caused by longwave radiation from tree branches, advected sensible heat and the snow itself when a sharp vapor pressure gradient exists.

Environmental Laboratory

For those people who enjoy viewing in the third dimension, soil moisture and temperature data from the environmental lab at Warrensburg, N. Y. are presented in Figures 3 & 4. This laboratory, operated as a cooperative venture with the College of Forestry, was described by Leaf and Leonard at the XIV IUFRO Congress section 21, München, Germany, 1967.



THREE RIVER HARDWOOD - ALBEDO - MAY 26, 1967 (Also April 28)

SEE 20x20 TO INCH

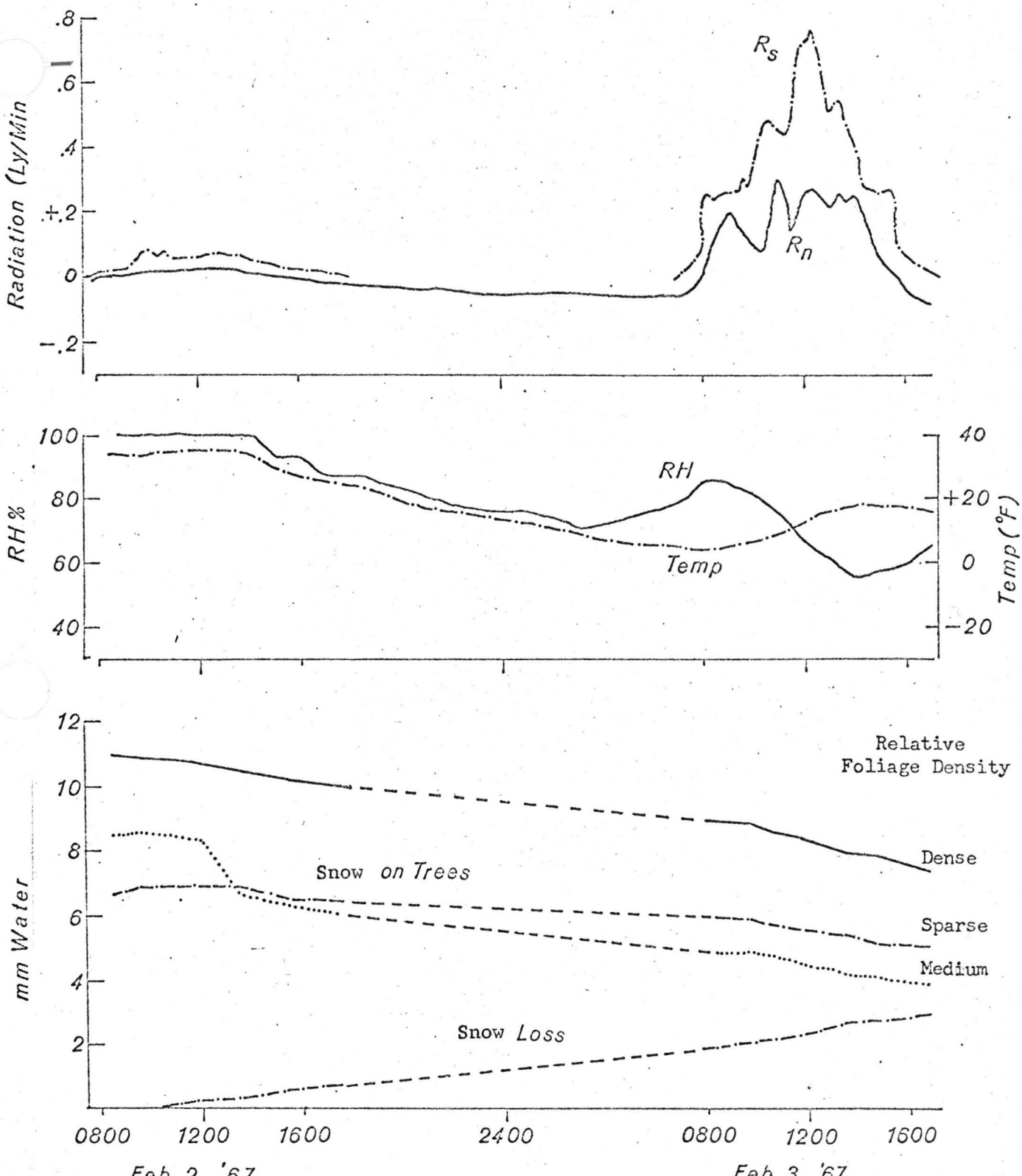
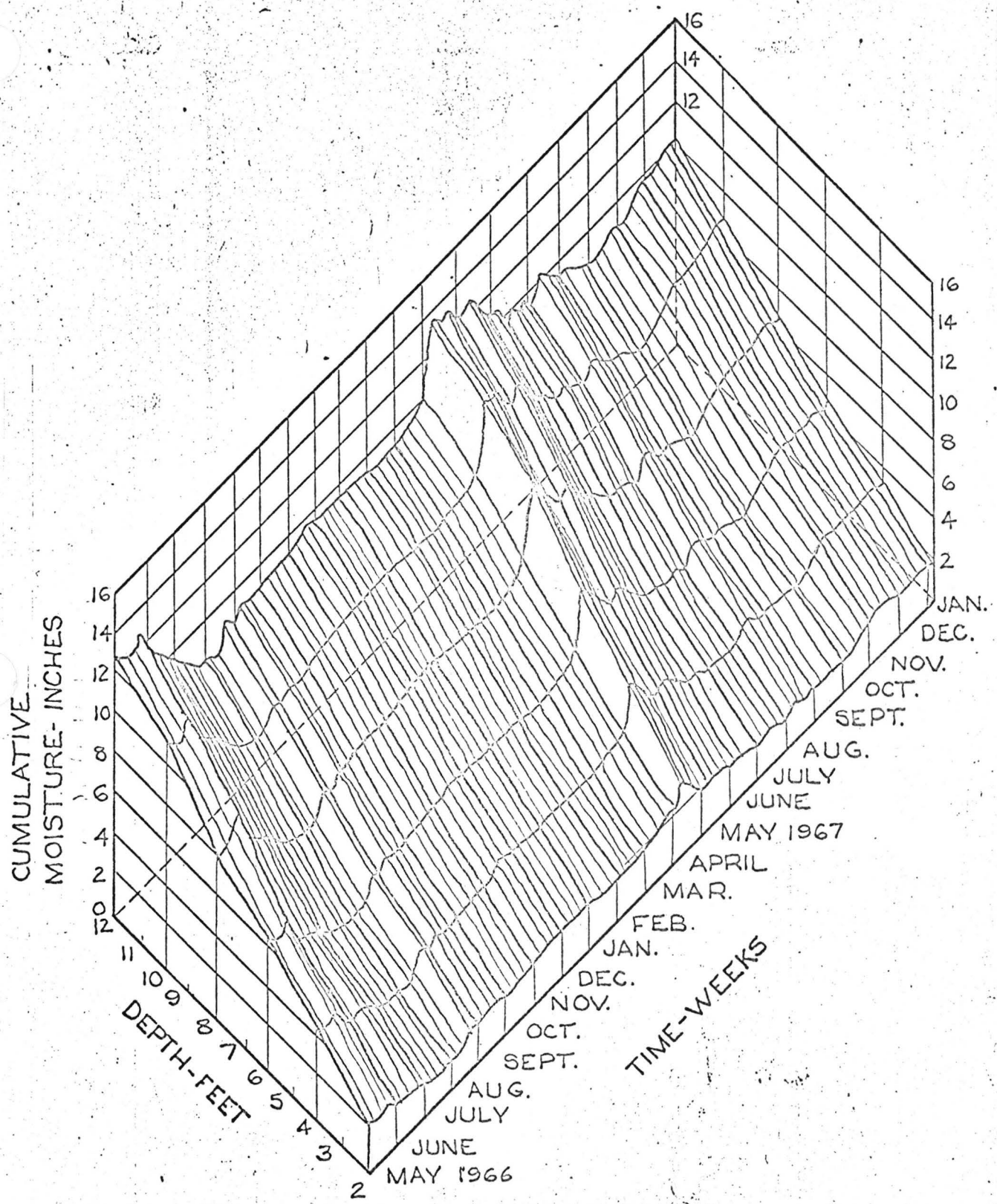
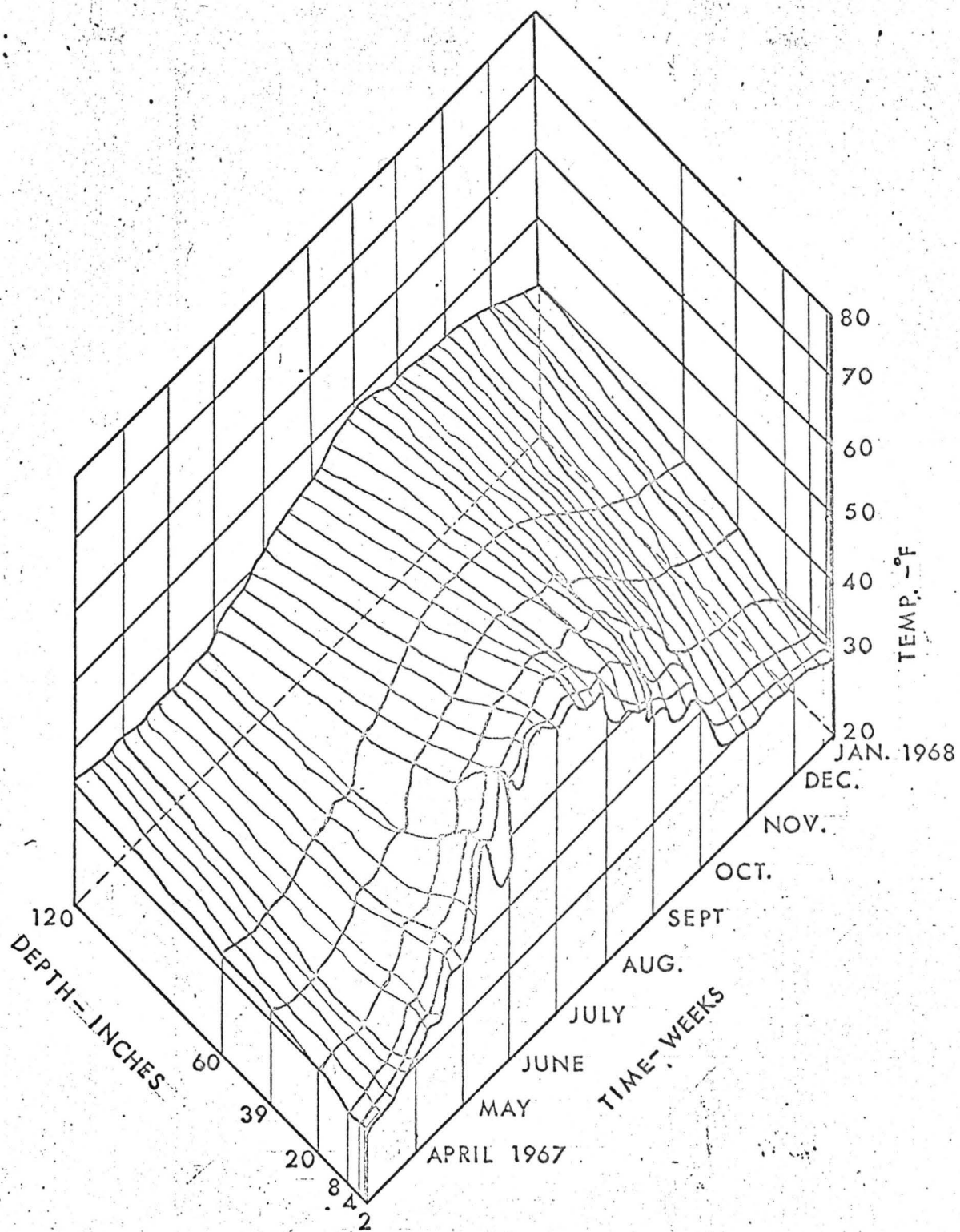


Figure 2. February 2, and 3, 1967. Patterns of solar radiation (R_s), net radiation (R_n), temperature, relative humidity (RH), and intercepted snow.



Mean soil moisture by depth and time, Warrensburg, N. Y.

Figure 3



Mean soil temperature by depth and time, Warrensburg, N. Y.

Figure 4

The moisture data presented in Figure 3 are the mean values from 8 sample neutron access tubes in a one-acre site located on a glacial outwash plain, classified as Hinckley loamy course sand. Measurements of soil moisture are taken at weekly intervals at two-foot-depth increments throughout the year.

Soil temperature data presented in Figure 4 are mean values of 4 stacks of thermocouples randomly located in the one-acre site. Each stack consists of 7 thermocouples at depths of 2, 4, 8, 20, 39, 60, and 120 inches depth in the soil.

---R. E. Leonard

PROJECT 1605 - FOREST RESTORATION OF STRIP-MINED LANDS

General

During the week of October 2, personnel from the Berea Field Unit participated in a training session for state reclamation inspectors from Kentucky, Tennessee, Virginia, West Virginia, Maryland, and Illinois. There were representatives of National Forest Administration from the Regional Office in Atlanta and the Daniel Boone, the Shawnee, and the Wayne-Hoosier National Forests. Also attending were personnel from the Department of Interior, Bureau of Mines.

The Northeastern Station is developing a cooperative agreement with the Pennsylvania Department of Mines and Mineral Industries to conduct studies of refuse or "gob" piles. These "gob" piles are formed from slate rock and roof coal separated from merchantable coal during the process of deep mining. These mounds of waste material range to over 100 acres in size. Some of the questions are: What is the areal extent and what has been done to date with the gob piles? What do they contribute in terms of water and air pollution? What more can be done to minimize the offsite effects?

We are in the process of developing a formal agreement with the Eastern Kentucky University at Richmond, Kentucky. Members of the Biology Department will conduct a survey of fish and aquatic insects in the experimental watersheds of Leatherwood Creek and Bear Branch. Another team will survey the areas for terrestrial forms of life. The surveys will be repeated periodically before, during, and following strip mining. From these surveys we hope to be more able to assess the influence of strip mining on other resources.

Recent personnel actions resulted in three new additions to our staff. Walter Davidson joined the research activities of the Kingston unit. He came from the shelterbelt research project at Bottineau, North Dakota. Two permanent research technician positions have been filled with Phil Marcum and Art Peterson. Peterson was employed here prior to entering the armed services in January 1966. Marcum came to us from the Kentucky Division of Forestry.

---Grant Davis

Hydrology

We are beginning to record some effects of strip-mining on stream flow in our Leatherwood Creek watershed. It appears that pit drainage is a factor which should not be neglected. Figure 1 shows four separate peaks resulting from strip-mine pit drainage. This tributary stream is immediately below the disturbed area. A mile down stream at another weir there was no effect.

Water quality is now beginning to show the influence of mining activities. Suspended sediment is increasing as is specific conductivity which indicates an increase in total dissolved solids. There has also been a slight decrease in pH. This is most apparent in the tributary stream below the mining. Dilution minimized the down-stream effect.

We are on the verge of initiating a subsurface moisture study with nuclear sensing equipment in western Kentucky on area-type stripped lands. The first major problem is: how do we put in access tubes on a rock pile? That is essentially what we must do. Soon we will try the Model B-30 drill, manufactured by Mobile Drilling Company, Inc., and equipped with 2-inch diameter auger with a carbide insert bit. We will report our success or failure in the next issue. In the meantime we will appreciate any suggestions or comments on equipment which will drill acceptable access holes on rocky sites.

---Willie R. Curtis

Revegetation

Hydroseeding--In the spring of 1967 two seed mixtures, each containing a softwood, hardwood, grass and a legume species, were hydroseeded on 32 plots on deep- and strip-mine spoils in the anthracite region of Pennsylvania. The seeding rate was predetermined together with lime, fertilizer and silva-fiber mulch which were used as treatments.

ure 1.--Hydrographs of Leatherwood A and C sh influence of strip-mine pit drainage,
Breathitt y, Kentucky
Nove r, 1967

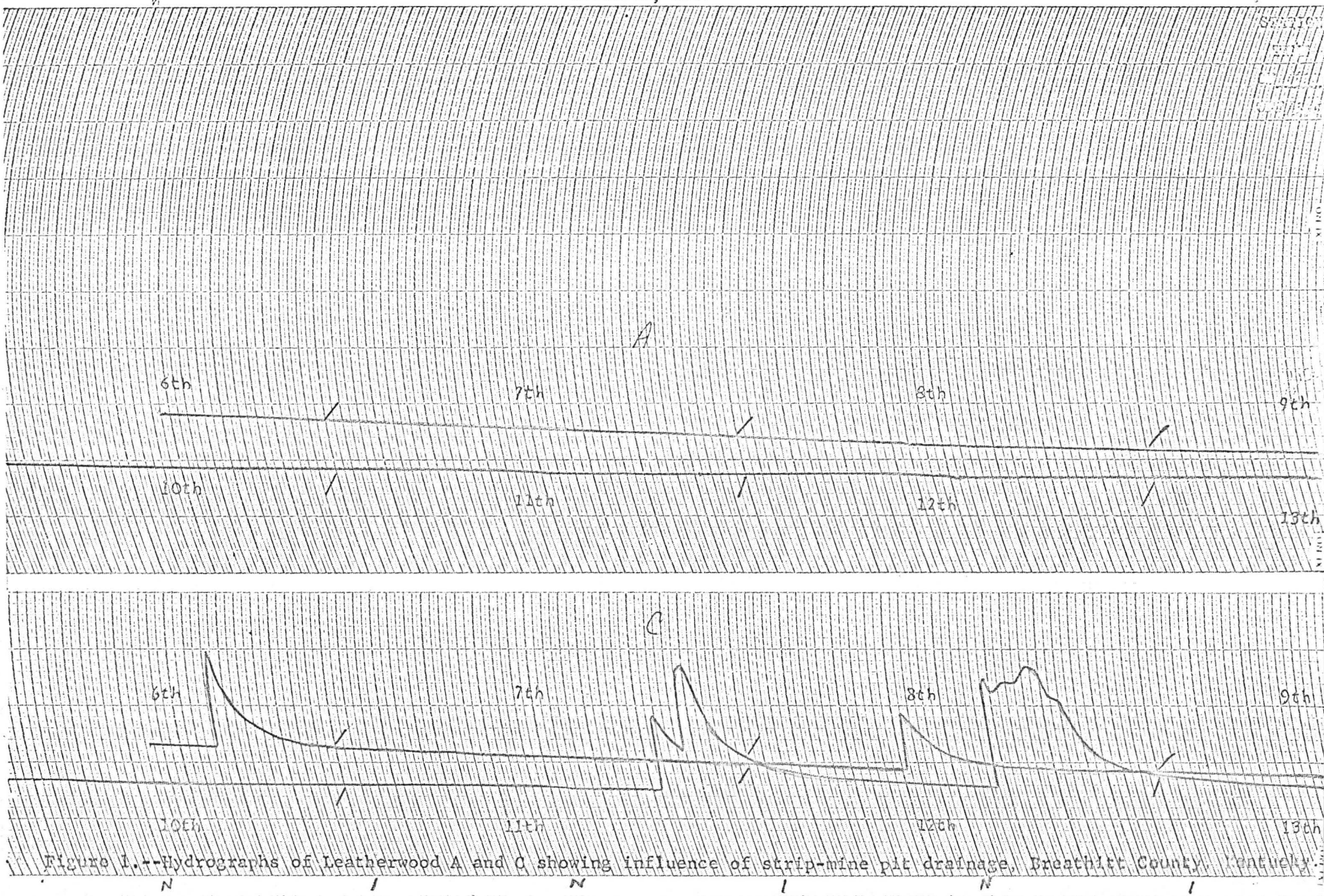


Figure 1.--Hydrographs of Leatherwood A and C showing influence of strip-mine pit drainage, Breathitt County, Kentucky.

The table below shows the number of seedlings (per acre) after the first growing season.

Number of tree, grass, and legume seedlings growing on anthracite coal spoils

Species	Coal breaker refuse (Carbonaceous shale)	Strip-mine spoil (Gray shale)
Mixture A	Number per acre	
Red pine	151	1,059
Gray birch	302	1,361
Rye grass	7,109	176,055
Lespedeza	81,951	176,358
Mixture B		
Scotch pine	0	1,664
Black locust	0	908
Tall fescue	14,069	307,189
Crownvetch	41,594	95,439

---M. Czapowskyj

Tubelings--A study is being initiated to investigate the effects of planting date on the survival of red and Scotch pine tubelings planted on bituminous spoils in Pennsylvania. The tubelings, started in a greenhouse, will be outplanted eight weeks after seeding. Two sets of tubelings are now in the greenhouse. Four outplantings will be made at four-week intervals starting on April 15, 1968. This will be the first planting trial of tubelings on coal-mine spoils in Pennsylvania.

---Walter H. Davidson

Fertilization of Trees--Spoils too acid for tree establishment and growth represent a relatively small acreage in the Appalachian coal fields but they are important due to their water pollutant potential and unsightly appearance. The problem then is to develop techniques that will improve survival and growth of selected species on these extremely acid sites.

In one field study we investigated the benefit to planted locust from liming, fertilizing, and mulching treatments on two extremely acid spoils. The fertilization treatment included dicalcium phosphate at 100 pounds of P_2O_5 per acre and ammonium nitrate at 50 pounds N per acre, applied in two slits near the planting hole. Hydrated lime at a rate of 15 tons per acre was applied and mixed into the surface six inches of spoil. The following treatments were compared with an untreated check: (1) lime alone, (2) lime plus N and P, and (3) lime, N and P, and a straw mulch. On both sites at the end of the second growing season the trees on the plots treated with lime and fertilizer were significantly taller than the trees on the check or lime only plots. On one site the mulch increased growth significantly but on the other site it did not.

The response of black locust to lime, fertilizer, and mulch treatments

Treatment	Mean height Second Growing Season	
	Site I (feet)	Site II (feet)
Check	2.1	1.3
Lime	2.7	2.9
Lime + Fertilizer	4.2	7.7
Lime + Fertilizer + Mulch	5.6	9.6

In other field trials, phosphate fertilization was emphasized because greenhouse trials have consistently shown a deficiency of phosphate limits legume growth on many spoils.

In one study, we compared locust survival and growth after applications of three types of phosphate fertilizer. Dicalcium phosphate, rock phosphate, and treble super-phosphate were placed in the planting holes at rates equivalent to 100 pounds P_2O_5 per acre when the trees are planted at a 6- x 6-foot spacing. Nitrogen at a rate equivalent to 100 pounds

per acre at 6- x 6-foot spacing was placed in slits six inches from the planting hole. The three phosphate fertilizers with supplemental nitrogen were compared with an untreated check, nitrogen alone, and dicalcium phosphate alone. After two growing seasons all fertilization treatments resulted in significantly greater growth than the check. Trees fertilized with treble super-phosphate plus nitrogen and dicalcium phosphate plus nitrogen were significantly taller than trees receiving the other treatments. Survival was significantly reduced by treble super-phosphate.

The response of black locust to the three phosphate fertilizers

Fertilizer treatment	Mean height 2 years growth (feet)	Survival (percent)
Check	4.7	100
Nitrogen	5.9	100
Dicalcium phosphate	6.7	100
Dicalcium phosphate plus nitrogen	8.0	100
Rock phosphate plus nitrogen	7.6	93
Treble super-phosphate plus nitrogen	8.4	87

---William T. Plass
William A. Berg

Aerial seeding--There is increasing interest in mechanized seeding equipment which will permit seeding large acreages at a low cost. The first device to gain and hold widespread recognition was the hydroseeder. Recently, however, there has been interest in seeding from aircraft. This spring we have cooperated with the states of Kentucky, West Virginia, their respective reclamation associations and several operators in trials involving seedings by fixed wing aircraft and a helicopter. In both instances grasses, legumes, and fertilizers were sown on several thousand acres of contour strip-mine benches in mountainous terrain. The seedings

included a wide range of sites and spoils. It is our intent to evaluate the effectiveness of these trial seedings at the end of the first growing season. Hopefully, these first attempts will encourage more trials so that we can compare results for more than one year.

---William T. Plass

Engineering

The study of factors associated with instability of strip-mine spoil outslopes is underway. Data on hand indicates that the danger of a spoilslide occurring on a strip-mine bench increases with the steepness of the natural slope below the coal outcrop line.

As terrain steepens, the proportion of operations worked by augering only as compared with strip or strip-and-auger operations increased. On slopes greater than 66 percent all operations were worked only by augering.

The configuration of the auger bench and its relative size seem to be factors which minimize sliding. A typical auger bench is less than 35 feet wide, has a low highwall, and a shallow, narrow fill bench. Its outslopes may be well supported at the toe by scalped brush intertwined with standing trees. The volume of overburden moved per unit length of outcrop is slight when compared with the typical strip or strip-and-auger operation.

The incidence of slides on operations designated "augering only" is relatively small in relation to length of disturbed outcrop.

Two curves have been prepared from available data (figure 2). Curve No. 1 shows the distribution of natural slope steepness below coal outcrops in eastern Kentucky. This curve is slightly skewed. The skewness reflects the fact that no contour type permits were issued on terrain less than 12 degrees or 21 percent slope, and only contour type permits are included in this study.

The plottings show the relationship between slide occurrence and natural slope steepness. All slides observed on all contour type operations--strip only, strip-and-auger, and auger only--are included. The population from which these operations were drawn are the jobs which were stripped and/or augered under the regulations in effect after July 1, 1966 in the state of Kentucky.

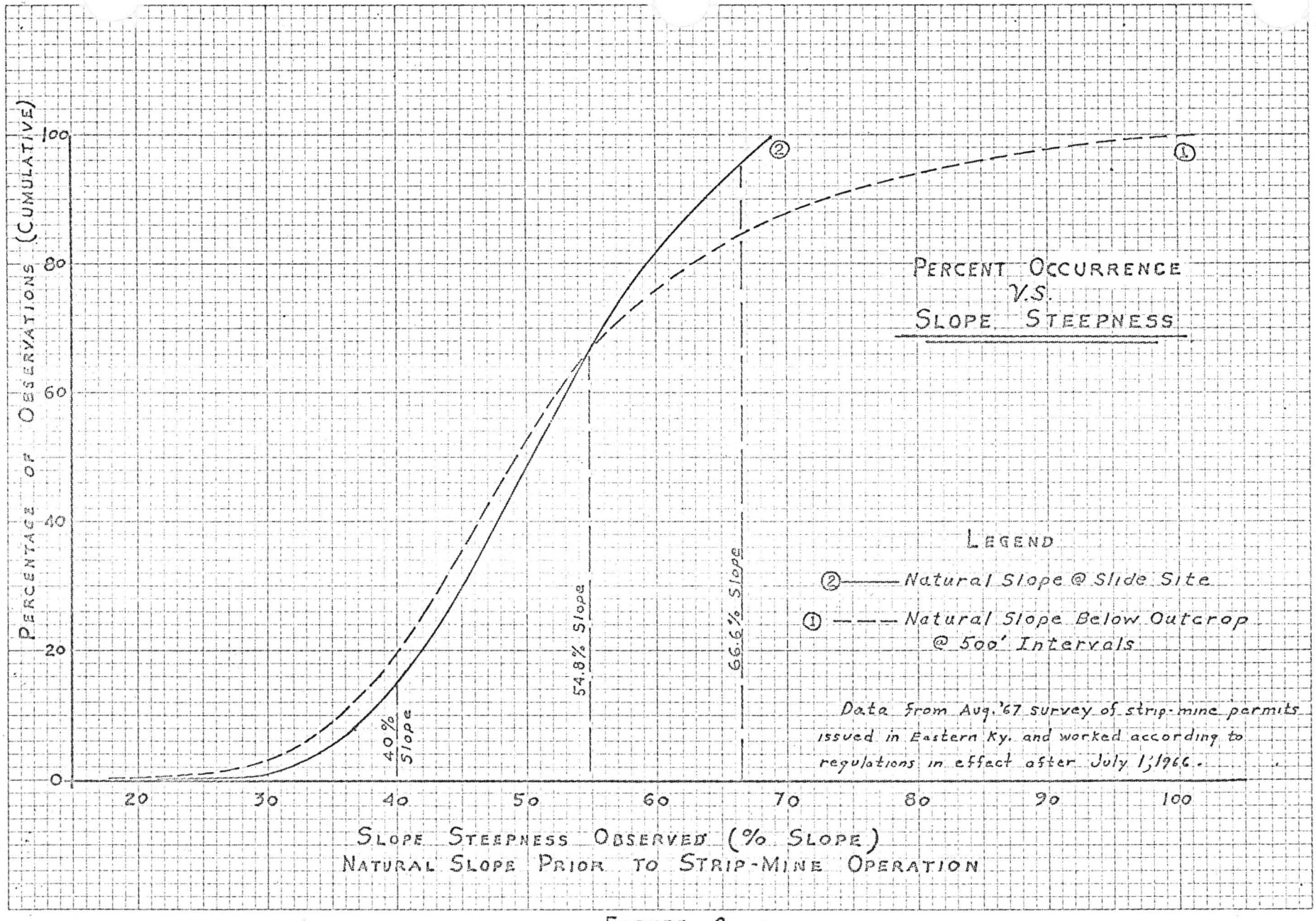

PERCENTAGE OF OBSERVATIONS (CUMULATIVE)
0
20
40
60
80
100
20
30
40
50
60
70
80
90
100
SLOPE STEEPNESS OBSERVED (% SLOPE)
NATURAL SLOPE PRIOR TO STRIP-MINE OPERATION
40% Slope
54.8% Slope
66.6% Slope
PERCENT OCCURRENCE
V.S.
SLOPE STEEPNESS
LEGEND
② Natural Slope @ Slide Site
① Natural Slope Below Outcrop @ 500' Intervals
Data from Aug. '67 survey of strip-mine permits issued in Eastern Ky. and worked according to regulations in effect after July 1, 1966.

FIGURE 2

The lower portion of Curve No. 2--that section plotted for natural slopes less than about 40 percent--indicate the increase of slide incidence with natural slope steepness.

The section of Curve No. 2 representing slopes greater than 40 percent indicates that slide incidence in this range increases faster than the incidence of slope observations. The two plottings converge at a natural slope of approximately 55 percent.

Of interest here is the fact that studies made at the University of Kentucky for the Kentucky Department of Stripmine Reclamation indicated that the natural angle of repose for saturated spoils in the eastern Kentucky coal region is 29 degrees. A slope of 29 degrees is equal to 55.5 percent.

Slide incidence on slopes less than 55 percent (Curve No. 2) is always below the incidence of slope observation (Curve No. 1), while slide incidence on slopes greater than 55 percent is always above the incidence of slope observations in this range.

At a natural slope of approximately 52 percent the incidence of slope observations begins to decrease markedly with slope steepness (Curve No. 1). The decrease in slide occurrence (Curve No. 2) becomes apparent at a natural slope of about 58 percent. This flexure in Curve No. 1 is simply a manifestation of normal distribution. The flexure in Curve No. 2 seems to contradict the implication of the lower portion of that same plotting. However, it is thought that the higher relative incidence of auger-only operations on terrain steeper than 55 percent natural slope and the lower incidence of slides typical of auger operations is responsible for this apparent contradiction.

---Perry Williams

PROJECT 1606 - MANAGEMENT OF STORM RUNOFF

During the past half-year we have compiled and summarized field and laboratory data for forthcoming manuscripts. The latest of our studies, i. e., the effects of forest tree root's development, growth, and decay on soil physical properties, has shown some initial results which may be of interest to our colleagues.

Soil Blocks for Root Study

In a previous report Dr. Aubertin discussed his initial field studies into forest tree root size, pattern, distribution, etc., in relation to soil type and depth. In the first examinations he has used an 8- x 20-foot soil block. Now after a full summer of measurement and after analysis of some of the data, he has reached some conclusions concerning the study technique and the results.

First, the present size block is much too large for our existing manpower and facilities to effectively dissect and measure. Further, the gross data are too voluminous for one professional man to later analyze in the lab and office. Based on the initial trials, he now suggests a smaller block, say 4 x 4 x 5 feet, taking random samples equivalent to 10 percent of the entire block. The samples, 6-inch cubes, should be dissected, mapped and saved for later laboratory analysis. This smaller block could be cut into an existing road cut, a strip-mined high wall, or any feasible open soil face that has the necessary tree species and soil type.

Secondly, where water-conducting channels are to be studied, the sample and surrounding area should be wetted with dye water before exposing the block--this will allow for a more natural disposition and distribution of the water within the soil.

Third, much specific information was gained concerning the soil in this block and the relation of rooting to the soil texture, density, depth, etc. This, plus specific recommendations as to investigative techniques, will be included in a forthcoming paper. Briefly, the soil is predominantly silt loam, underlain at relatively shallow depths by clay loam and clay. A great deal of textural and structural variability by depth was found within the block from one side to the others.

Fourth, live root diameters were generally smaller than those of the old root channels, but it must be remembered that we have no idea of the age or size of the previous trees from which the old root channels have arisen. (Many of these old channels are still lined with a persistent bark sheath.) Live roots are concentrated in the 3-12 inch depth, and old channels are scattered throughout the 6-24 inch depth. The present stand on this site is predominantly black oak, but indications are that prior to World War I, this area contained a heavy stocking of chestnut.

Fifth, the greatest number of living roots and old root channels were found in the upper 24 inches. Scattered roots were found down to 6 feet, but when the soil texture was predominantly clay, these tended to follow existing root channels or structural cracks.

Finally, a great deal of animal activity was found in the upper horizons, and was generally associated with large roots or stones. The amount of inter-connection, extent, continuity, etc., was impossible to investigate because of the great amount of work and time involved in mapping each individual 6-inch block on the gridded faces.

Micro-influence of Forest Tree Roots

Along with Dr. Aubertin's studies of root habits in the field, a cooperative aid study with the Ohio State University is giving us some important leads into micro-influence of forest tree roots on physical properties, such as density, structure, and spatial arrangement of forest soil particles. Two soils, a Clymer loam (formerly in the Keene series) and a Miami silt loam were chosen. Large blocks of soil were frozen in place with liquid nitrogen, extracted, impregnated with plastic mixture (Castolite-Styrene) under vacuum and then cut into thin sections for examination under a petrographic microscope.

A linear-transect method was used to determine volume percentages and distribution of pore space. The measurements were compared with those from standard lab techniques such as particle density, bulk density, and 60 cm. tension. The micrometric technique gave a close comparison of larger non-capillary pore percentages as determined by volume-weight and moisture retention analyses. However, in the extremely permeable A1 horizons, standard techniques underestimated the percentage of large pores. Specifically, it was learned that 2.5 percent of the pore space contained 22 pores in the 0.1-0.2 mm class range while 3.9 percent of the pore space contained only 3 pores in the 1.0 to 2.0 mm diameter range. This substantiates belief that a few large pores may be more important to saturated permeability than the balance of pores in smaller range classes.

As Dr. Aubertin found earlier on the same soil, roots that were found in the clay horizons having bulk densities of 1.74, tended to follow and develop in structural cracks and existing channels. In the zones of clay illuviation, there was an accumulation of elongated clay particles oriented parallel to the root (vertical) axis. The orientation and the packing appears to be due to the effect of normal wetting and drying, and to radial pressure exerted by the growing root. Thus the soil material immediately adjacent to the root is finer textured and less permeable to water and air, but extremely stable to help explain the presence of old, decayed root channels. In places a narrow annular space was found between the root surface and the clay particles.

The researchers feel that in these horizons where clay has accumulated and particle orientation is pronounced that the thin, somewhat compacted layer of clay particles would reduce the movement of soil water and/or air to or away from the roots.

The above are a few of the more important findings arising from these root studies, but they do substantiate soil scientists' beliefs that casual sampling of forest soil for examination of soil physical properties may not give a true picture of the important micro-effects of roots on soil structure, density, and water-transmitting capacity.

---R. Z. Whipkey

Informal Root Symposium

To stimulate interest in tree root research, to obtain some coordination of effort, and hopefully to arrange for a later, more comprehensive and formal forest tree root symposium, Dr. Aubertin and Walter Lyford (of the Harvard Forest) have arranged an informal symposium at the Harvard Forest for late summer. At first, Gerald and Walt had planned to invite 10 to 15 scientists actively engaged in specific areas of root research. However, the whole idea snowballed and within a short time they were deluged with potential participants from all over the U.S. (and several workers from Australia and Canada). With a great deal of regret, they have had to turn down almost as many requests as they have accepted (now 34 active participants); however, the meeting place facilities are now overtaxed and some of the informality of the meeting as originally planned may be lost. But we hope to publish a complete summarization of the meeting, and furthermore, hope that a meeting can be arranged for the near future--this will allow everyone interested in tree root research to attend.

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